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Floating UPS Ground February 5, 2004, Minor Shock

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April 5, 2005

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Floating UPS Ground February 5, 2004

Minor Shock



Gary Dreifuerst
NIF Safety Engineer
February 9, 2004

The Incident

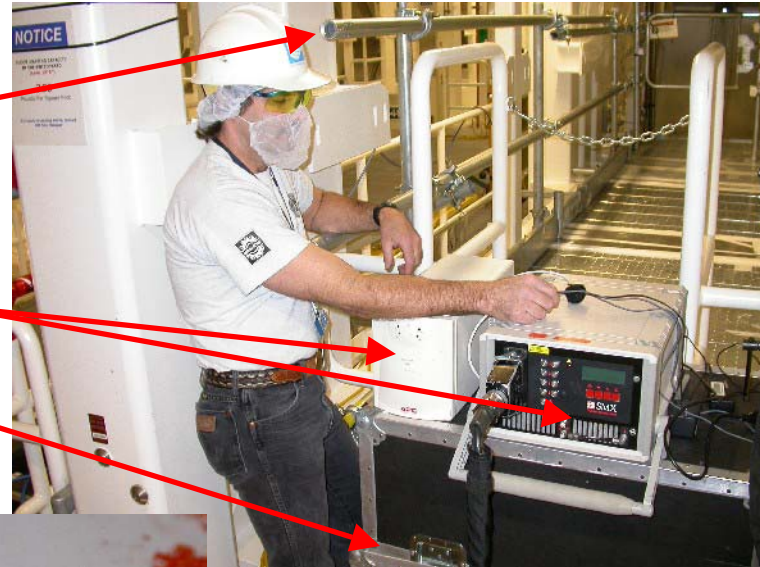


- Normal Day's Work in SY2
 - Setup Precision Laser Survey Equipment
 - ~11am “Caught” Arm Hair on UPS Top Panel
 - ~3:20pm, Same Arm Feeling Again--Maybe this is a SHOCK!!!
- Not a Normal Day Anymore
 - Worker notifies his NIF Supervisor, who calls NIF Management and then 911 is called
 - Always call 911 first in an Emergency
- To Avoid Equipment Problems
 - Always do a Visual Inspection of Your Tools Before Using Them
 - Look for Signs that it was Reworked and not Reassembled Completely
 - If in Doubt--DO NOT USE IT--Contact a Subject Matter Expert

The Incident Scene



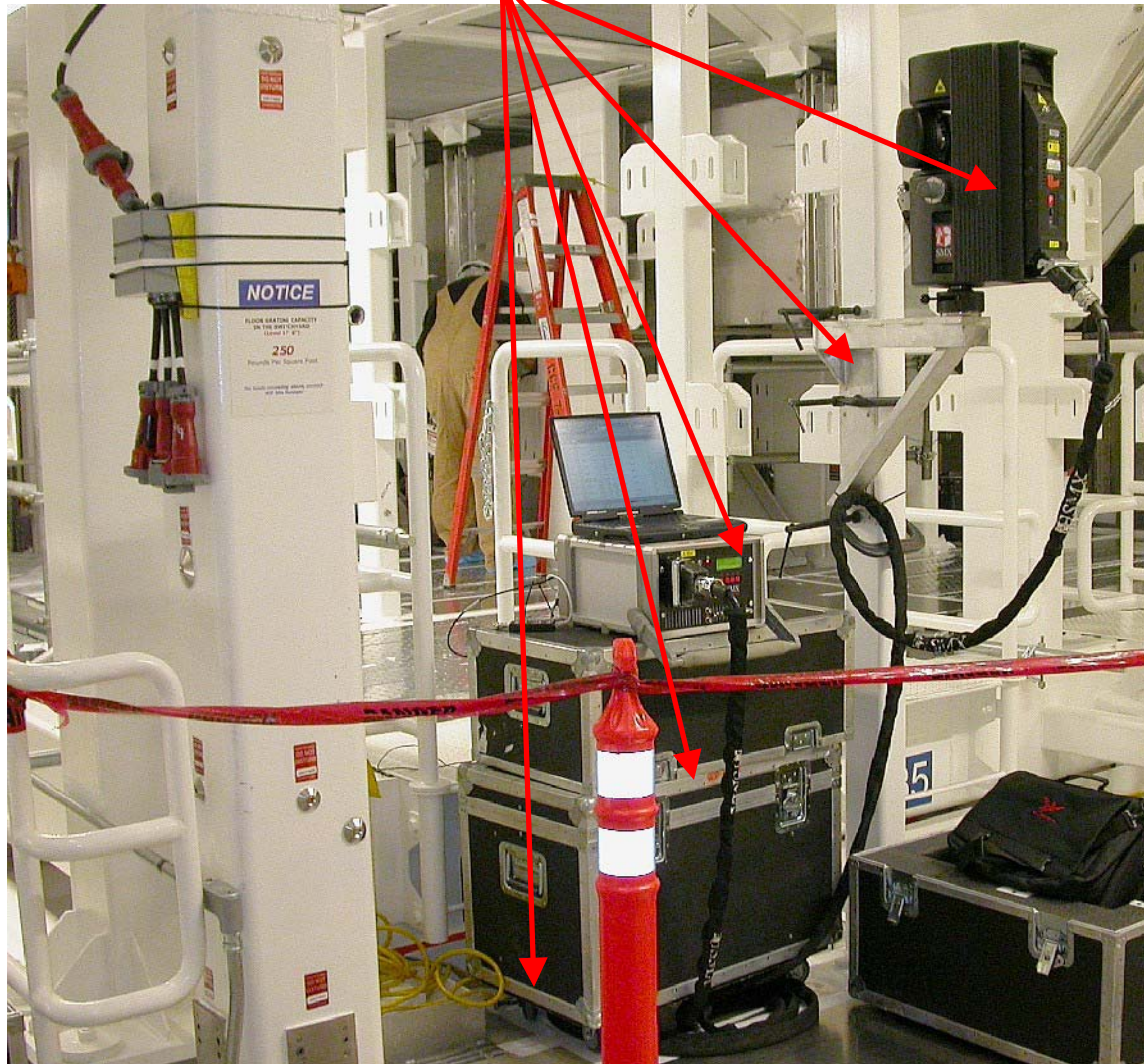
- Laptop was Removed Earlier from Top of SMX
- Grounded Scaffolding
- Ungrounded (54VAC) Chassis
- Ungrounded (54VAC) Edging
- UPS Paint Nicks



The Incident Scene – Big Picture



- UPS was removed
- Equipment at 54 VAC above Ground



Chassis Rear at Scene



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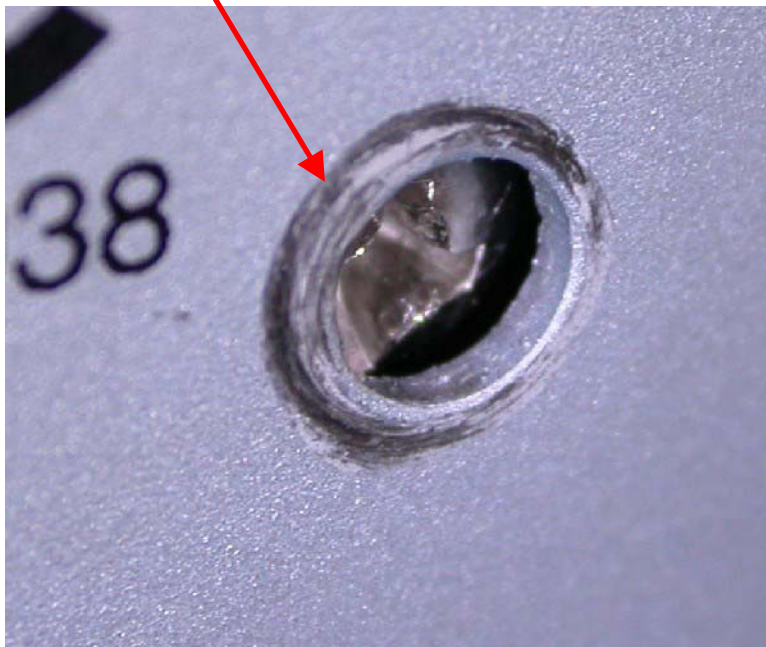
- The Clue is Here, It's Really Small
- Improperly Reassembled Chassis has Ground Screw INSIDE Chassis



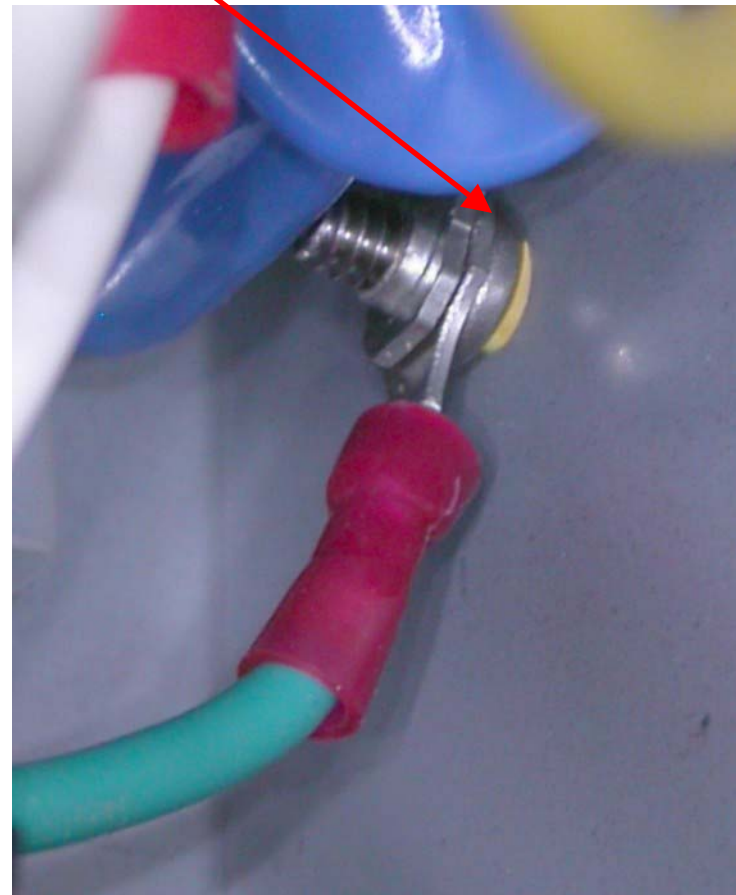
Inside the UPS

- Ground Connection Depends on a Bolt that Connects Green Wire from Cord to Chassis and to PWB Tab

— Angle View shows Scoring

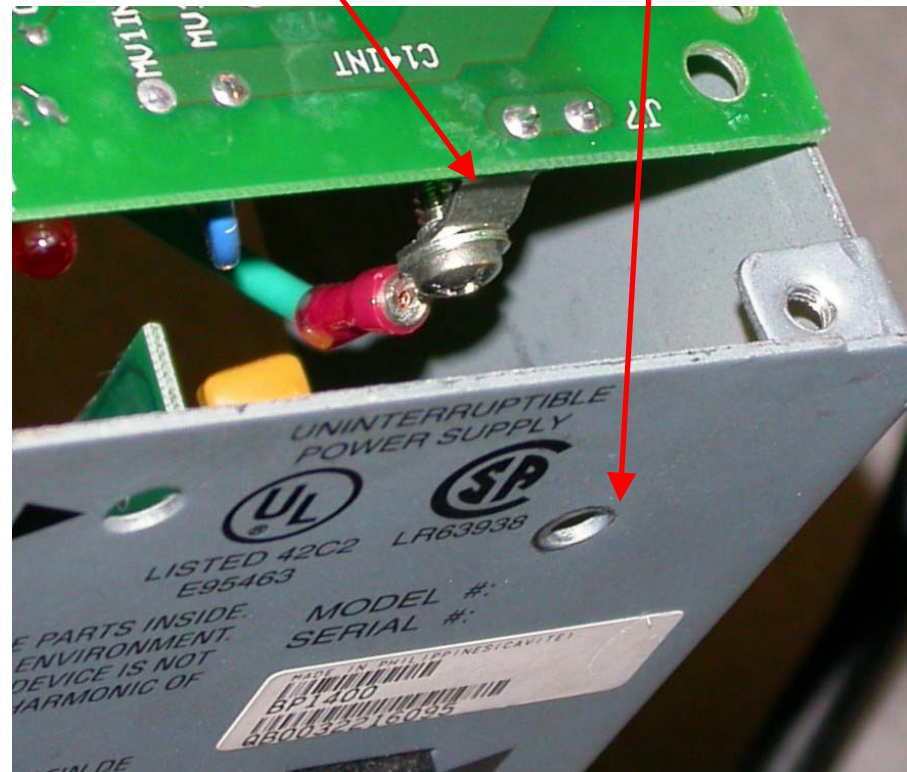
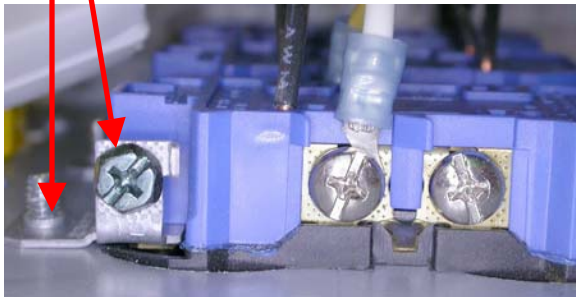


— Screw-Chassis Gap so Close



Inside the UPS - Receptacle Bonding

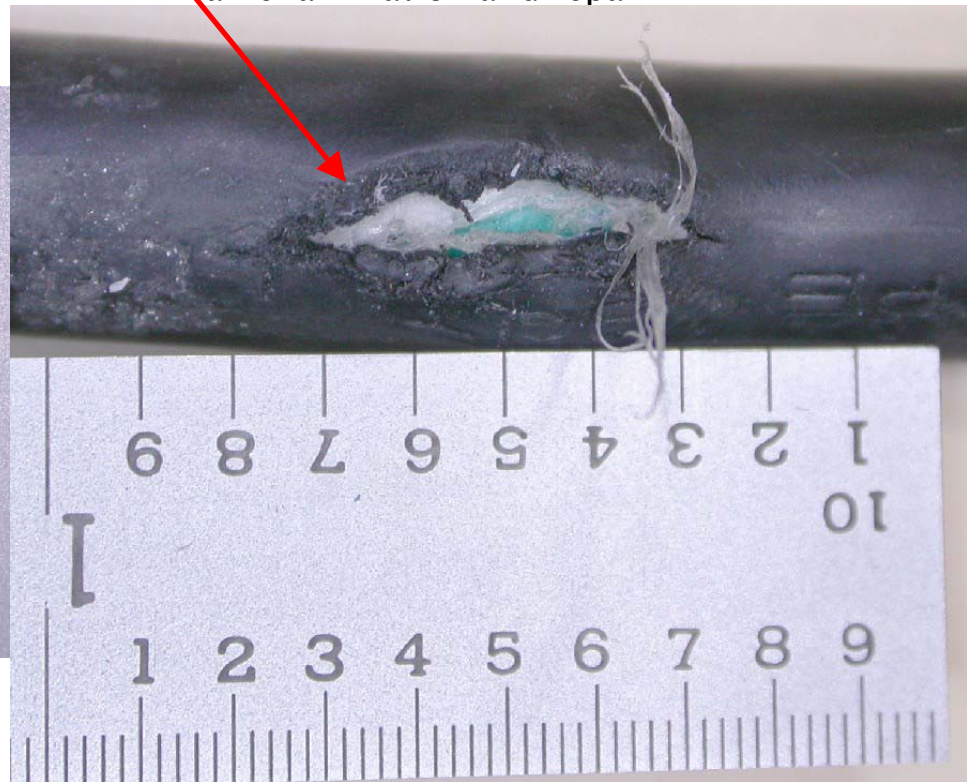
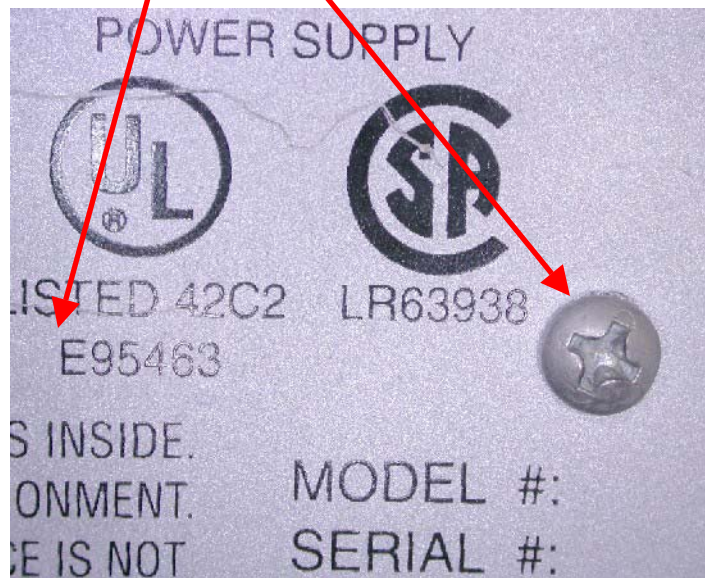
- Ground Connection Depends on a Bolt that Connects Green Wire from Cord to Chassis Plate and to PWB Tab
 - No Wired Connection to Ground Tab
 - Receptacle Ground
 - Depends on Chassis
 - PWB Tab J7
 - Ground Hole



A Good UPS and the Damaged Cord



- Unmodified UPS Tests out Perfectly and Early Clue to the Problem
 - UL Listing
 - Listing Number
 - Proper Ground Screw
 - Tear in Jacket of UPS Power Cable
 - This did not affect the UPS Grounding
 - Rejection of the UPS for this may have forced an examination and repair

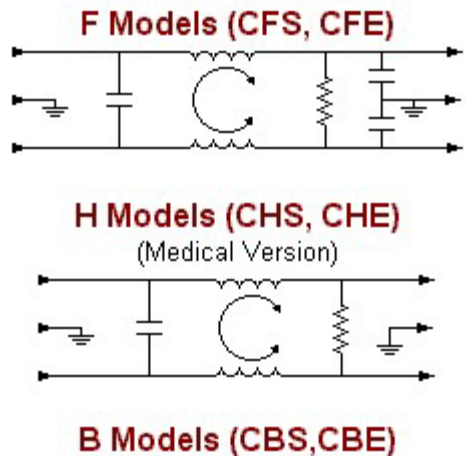


RFI Filter Circuit and Loss of Ground

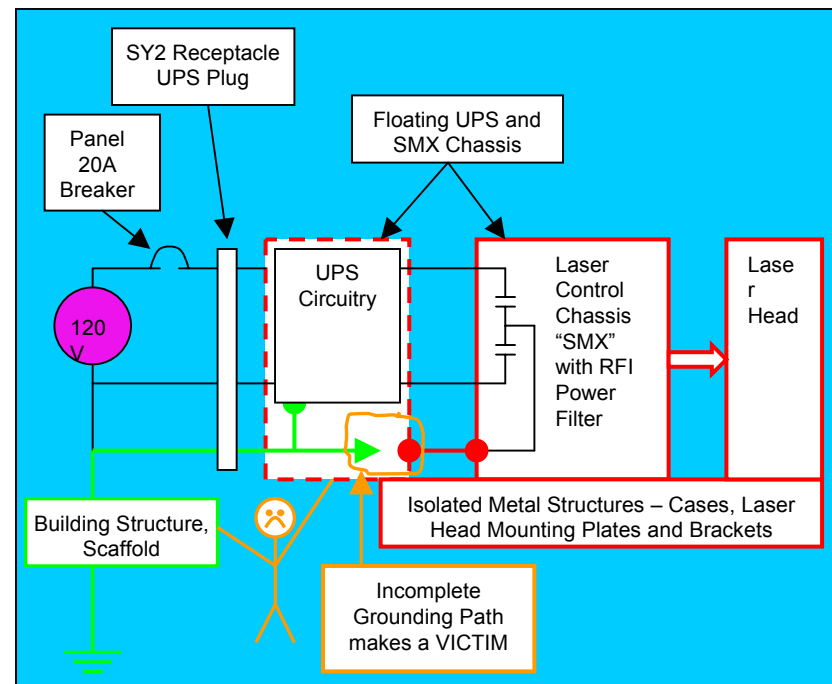
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- The Capacitive Filter Depends on a Ground Terminal to return the Filter Current
 - Without a Ground Connection, Current is Injected into the Chassis
 - Typical Chassis RFI Filter shown Below

Electrical Schematic



- The Output Receptacle of the UPS was not Bonded to the Input “Green” Wire
 - Load RFI Filter Injected Current into all the Chassis



Ground Current Measurements



- Ground Current was Measured using a 10 kOhm resistor between the Floating UPS Chassis and Ground as the SMX Laser Load Condition was Varied.
 - The Last Line Gives the Condition that puts an Upper Limit on the Worker's Shock

AC Current to Ground (VICTIM)	Chassis Voltage to Ground	Chassis Resistance to Ground	Load Type	Load Status
0.8 uA	8 VAC	10 MOhm DVM	No Load	
0.9 uA	9.3 VAC	10 MOhm DVM	SMX Plugged In	SMX Off
5.4 uA	54 VAC	10 MOhm DVM	SMX Plugged In	SMX On
0.02 mA	0.197 VAC	10 kOhm Resistor	No Load	
0.03 mA	0.297 VAC	10 kOhm Resistor	SMX Plugged In	SMX Off
0.93 mA	9.34 VAC	10 kOhm Resistor	SMX Plugged In	SMX On

ES&H Manual Doc 16.1 Human Effects



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- Based on the Victim's Symptoms

- Shock Exceeded the Slight Sensation (0.4 mA)
- Not Consistently Recognized thus below the Perception Threshold (1.1 mA)

- Table Effects fit the Measured Current well

Table B-1. Effects of electric current on the human body (Ref. 1).

Effect/feeling	Direct current (mA)		Alternating current (mA)				Incident severity
	150 lb	115 lb	60 Hz		10,000 Hz		
			150 lb	115 lb	150 lb	115 lb	
Slight sensation	1	0.6	0.4	0.3	7	5	None
Perception threshold	5.2	3.5	1.1	0.7	12	8	None
Shock not painful	9	6	1.8	1.2	17	11	None
Shock painful	62	41	9	6	55	37	Spasm, indirect injury
Muscle clamps source	76	51	16	10.5	75	50	Possibly fatal
Respiratory arrest	170	109	30	19	180	95	Frequently fatal
≥0.03-s vent. fibril.	1300	870	1000	670	1100	740	Probably fatal
≥3-s vent. fibril.	500	370	100	67	500	340	Probably fatal
≥5-s vent. fibril.	375	250	75	50	375	250	Probably fatal
Cardiac arrest	--	--	4000	4000	--	--	Possibly fatal
Organs burn	--	--	5000	5000	--	--	Fatal if it is a vital organ

After Loss of Ground - The Next Incident



- Without Reporting this “Minor” Shock, the Worker would allow an Ungrounded Chassis to Continue to be Used.
- A Second Failure in this System may have been an Insulation Failure from the 120VAC “Hot” Conductor to the Ungrounded Chassis.
- No Current Limiting Capacitance would be Available to Protect the Victim and Now a Life-Threatening Shock Could Happen.
- The 20A Circuit Breaker would be the only Current Limiting Device
 - This Does Not Protect Human Life
- A GFCI (Ground Fault Circuit Interrupter) would limit the Current to Ground to 5 mA (± 1 mA)
 - This Does Protect Human Life
- **Always Report Shocks, Even if only Minor**